LOAD FREQUENCY CONTROL USING ADAPTIVE AND FUZZY BASED CONTROLLER FOR HYBRID MICRO-GRID SYSTEM

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy of Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

A hibrid mikro grid adalah subset dan menjadi penting dalam grid kuasa moden, yang menggunakan inersia, dan bukan inersia Diedarkan Generations (DGS) untuk membekalkan kuasa kepada masyarakat di kawasan kecil daripada kawasan yang luas. Mikro grid boleh beroperasi dalam segerak dengan utiliti grid atau sebagai berasingan (islanded). Ia adalah satu kaedah yang berguna untuk mencapai pengembangan rangkaian tetapi mempunyai beberapa isu. Mod pemindahan dari grid utama tempatan untuk mod berasingan menghadapi banyak cabaran, berkaitan dengan perubahan beban yang besar tiba-tiba berubah dan kehilangan grid elektrik utama. Apabila mikro-grid terputus, dan dalam mod berasingan, kuasa aktif dan reaktif perlu dikawal oleh unit-unit DG. laporan penyelidikan ini termasuk analisis Kawalan Frekuensi Beban (LFC) untuk mengawal hibrid mikro grid disambungkan ke grid, dan apabila beroperasi dalam mod berasingan. Manfaat kaedah kawalan adalah untuk membetulkan penyimpangan kekerapan semasa syarat-syarat operasi berasingan (islanded) sebagai DG berterusan akan menyuntik kuasa pada tahap yang dikehendaki. Strategi kawalan mikro-grid disiasat dalam kerja-kerja ini termasuk analisis sambutan fana sisihan frekuensi dan perkongsian kuasa dalam kedua-dua operasi iaitu sambungan dengan grid dan berasingan (islanded) mod operasi mikro grid. Pengawal PI adaptif digunakan dengan menggunakan peraturan MIT berdasarkan Kawalan Penyesuaian Rujukan Model (MRAC) untuk kelancaran mikro grid dari grid utama tempatan ke mod berasingan (islanded) untuk mengelakkan penyimpangan kekerapan yang tinggi. Kemudian, pengawal Rangkaian Neural Buatan (ANN) digunakan untuk mengemas kini keluaran MRAC dan meningkatkan prestasi operasi grid mikro. Dari kajian simulasi, jelas bahawa pengawal berasaskan MRAC-ANN berkesan dapat mengurangkan ayunan (transient) dan mengurangkan masa penyelesaian. Kawalan Jadual Logik Fuzzy (FLTC) digunakan di LFC di sistem grid mikro untuk mengawal frekuensi sistem, dan memberikan prestasi yang diingini terhadap perubahan beban secara tiba-tiba dan gangguan kerosakan didalam mikro grid, meningkatkan perbezaan kekerapan dan keluaran kuasa output. Untuk pengesahan, semua analisis dibandingkan dengan pengawal PI konvensional dan hasilnya menunjukkan pengawal yang dicadangkan mengatasi pengawal PI konvensional dalam dengan menunjukkan keputusan yang memberangsangkan. Pengawal yang dicadangkan boleh diklasifikasikan mudah dan mudah dilaksanakan. Oleh itu, pengawal LFC yang dicadangkan ini boleh menyumbang kepada peningkatan penggunaan tenaga ke dalam persekitaran mikro-grid.

ABSTRACT

A hybrid micro-grid is a subset and becomes vital in the modern power grid, which is using inertia and non-inertia Distributed Generations (DGs) to supply power to communities in the small-scale area rather than vast regions. A micro-grid can operate in synchronous with the grid utility or as islanding; it is a useful method of achieving network expansion but have some issues. The transfer mode from the local main grid to islanding mode faces many challenges, related to significant load changes suddenly and the loss of the main electricity grid. When the micro-grid is disconnected, and in islanded mode, the active and reactive power needs to be controlled by the DG units. This research report includes an analysis of Load Frequency Control (LFC) for control of a hybrid micro-grid connected to the grid, and when operating in islanded mode. The benefit of this method of control is to correct frequency deviations during conditions of islanded operation as the DG would continually inject power at the desired level. The micro-grid control strategies investigated in this work included an analysis of the transient response of the frequency deviation and power sharing in both grid-connected and islanded modes of micro-grid operation. The adaptive PI controller is utilized by applying a Model Reference Adaptive Control (MRAC) based MIT rule for a smooth transfer micro-grid from the local main grid to the islanded mode for avoiding high-frequency deviations. Then, an Artificial Neural Network (ANN) controller is used to update the output of MRAC and to enhance micro-grid operation performance. From the simulation studies, it is clear that MRAC-ANN based controller can effectively damp out the oscillations and reduce the settling time. The Fuzzy Logic Table Control (FLTC) is employed in LFC at islanded micro-grid system to regulate the system‘s frequency, and provides desirable performance against sudden load changes and fault disturbances, improving the frequency deviation and output power variation. For verification, all the analyses are compared with conventional PI controller and the results show the proposed controller outperform the conventional PI controller in promising response. The proposed controller can classify simple and easy to implement. Therefore, these proposed controllers of LFC can contribute to the expanding the energy utilization into the micro-grid environment.

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LIST OF SYMBOLS

Δf	Frequency Error
E_g	Internal Voltage
T_{mech}	Mechanical Torque
T_{elec}	Electric Torque
ω	Rotational Speed
ΔP_{Gov}	Speed Governor
ΔPr	Change in Reference Power
P_{ha}	Hydraulic Valve Actuator
P_{de}	Load Demand
P_{Tu}	Change in Turbine Power
P_m	Electromechanical Power
P_e	Electric Power
P_{acc}	Acceleration Power
K_i	Gain Control
J	Moment of Inertia
H	Constant of Inertia
δ	Angle Delta
Kp	Proportional Action Coefficient
Ki	Integral Action Coefficient
θ	Synchronous Impedance Angle
V_t	Terminal Voltage
V_{ref}	Voltage Reference
ΔV	Voltage Error

X_{eq}	Equivalent Reactance
P	Active Power
Q	Reactive Power
$F(\vartheta)$	Loss function
$\mathcal{E}$	Error between the Process output and the Reference model
$\mathbb{y}$	Measured Output
$\mathbb{y}_{\mathrm{m}}$	Reference Model
γ	Gamma
$\mathbb{u}$	Control Variable
$\vartheta 1$	Controller Parameter 1
$\vartheta 2$	Controller Parameter 2
w_{ji}	Weight Connection
2-D	Two-Dimensional Function

LIST OF ABBREVIATIONS

AC	Alternate Current
ACE	Area Control Error
AGC	Automatic Generation Control
ANN	Neural Network
AVR	Automatic Voltage Regulator
CERTS	Consortium for Electric Reliability Technology Solutions
DC	Direct Current
DER	Distributed Energy Resources
DG	Distributed Generators
ESS	Energy Storage System
FLC	Fuzzy Logic Control
FLTC	Fuzzy Logic Table Control
IC	Incremental Conductance
IG	Induction Generator
IGBTs	Insulated Gate Bipolar Transistors
LFC	Load Frequency Control
LI	Lithium Ion
LQR	Linear Quadratic Regulators
MG	Micro-grid
MGCC	Micro-Grid Centralized Control
MIT	Massachusetts Institute of Technology
MPPT	Maximum Power Point Tracking
MRAC	Model Reference Adaptive Control

PCC	Point of Common Coupling
PI	Proportional-Integral
PLL	Phase Lock Loop
PV	Photovoltaic
RES	Renewable Energy Sources
SG	Synchronous Generator
SOC	State of Charge
STS	Static Transfer Switch
VSC	Voltage Source Converter
VSG	Virtual Synchronous Generator
WTG	Wind Turbine Generator
Z-N	Ziegler-Nichols

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